Europa Clipper: Update to OPAG

Bob Pappalardo

Jet Propulsion Laboratory, California Institute of Technology

Sept. 6, 2017

Overview

- PSG #5 Recap
- Tour Update
- Spacecraft Configuration
- Prototype Hardware
- PDR Schedule
- Science Traceability and Alignment Framework

PSG Meeting #5 Recap

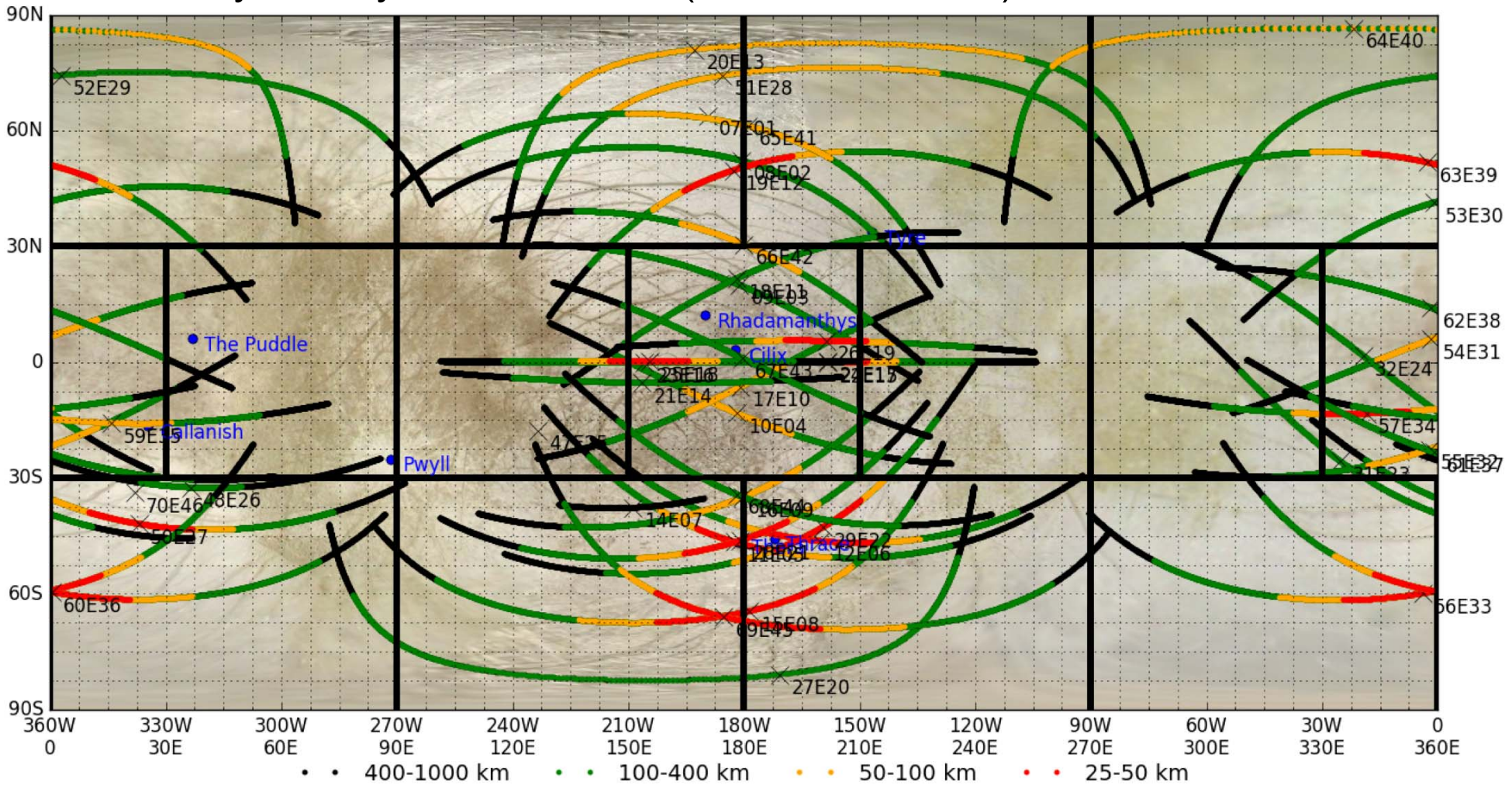
May 17–19, 2017

- Discuss science actions from MDR-SRR
- Evaluate tour options for Preliminary Design Reviews
- Outline Potential Collaborative Data Products
  - Quick-look and higher-level data products
- Establish foundation for Mission System plans:
  - Science observation planning & analysis tools
  - Data processing, analysis, & archiving
  - Feed-forward & latency
- Begin to define an Integrated Plume Search strategy
  - Established a new Plumes Focus Group
  - Co-Chairs: Matt Hedman & Carly Howett
- Confer on Rules of the Road development
- Discuss Project communications and remote collaborations
- Review Science Traceability and Alignment Framework for traceability from Level 1 science requirements to science observation types
- Nominate TWG Co-Chairs for rotation
  - Britney Schmidt (Habitability), Julie Rathbun (Geology), James Roberts (Interior), Murthy Gudipati (Composition)

Tour Update

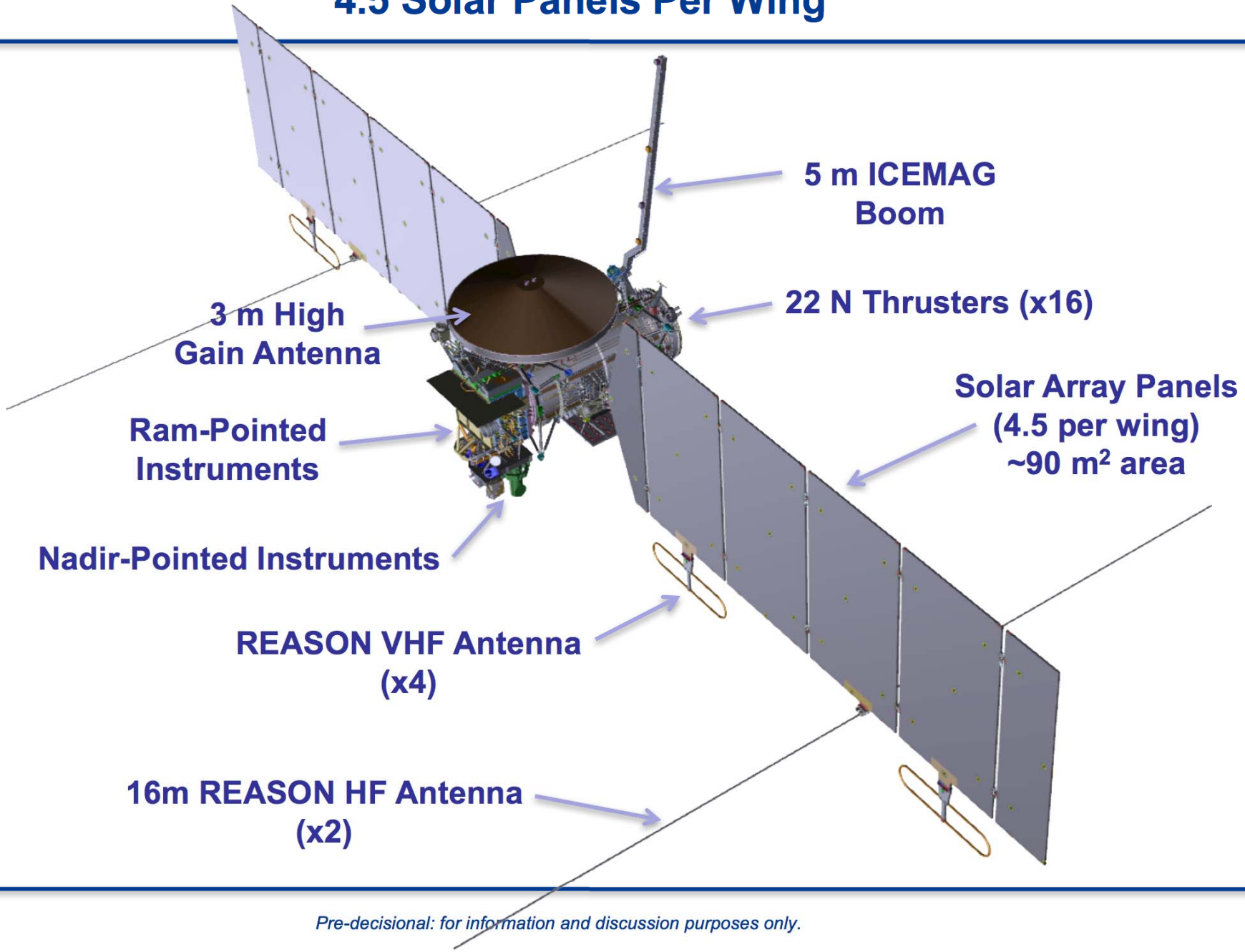
17F12_v2

- Tweaked to include lower flybys in leading hemisphere
- Now fly directly over Callanish (<100 km altitude)!



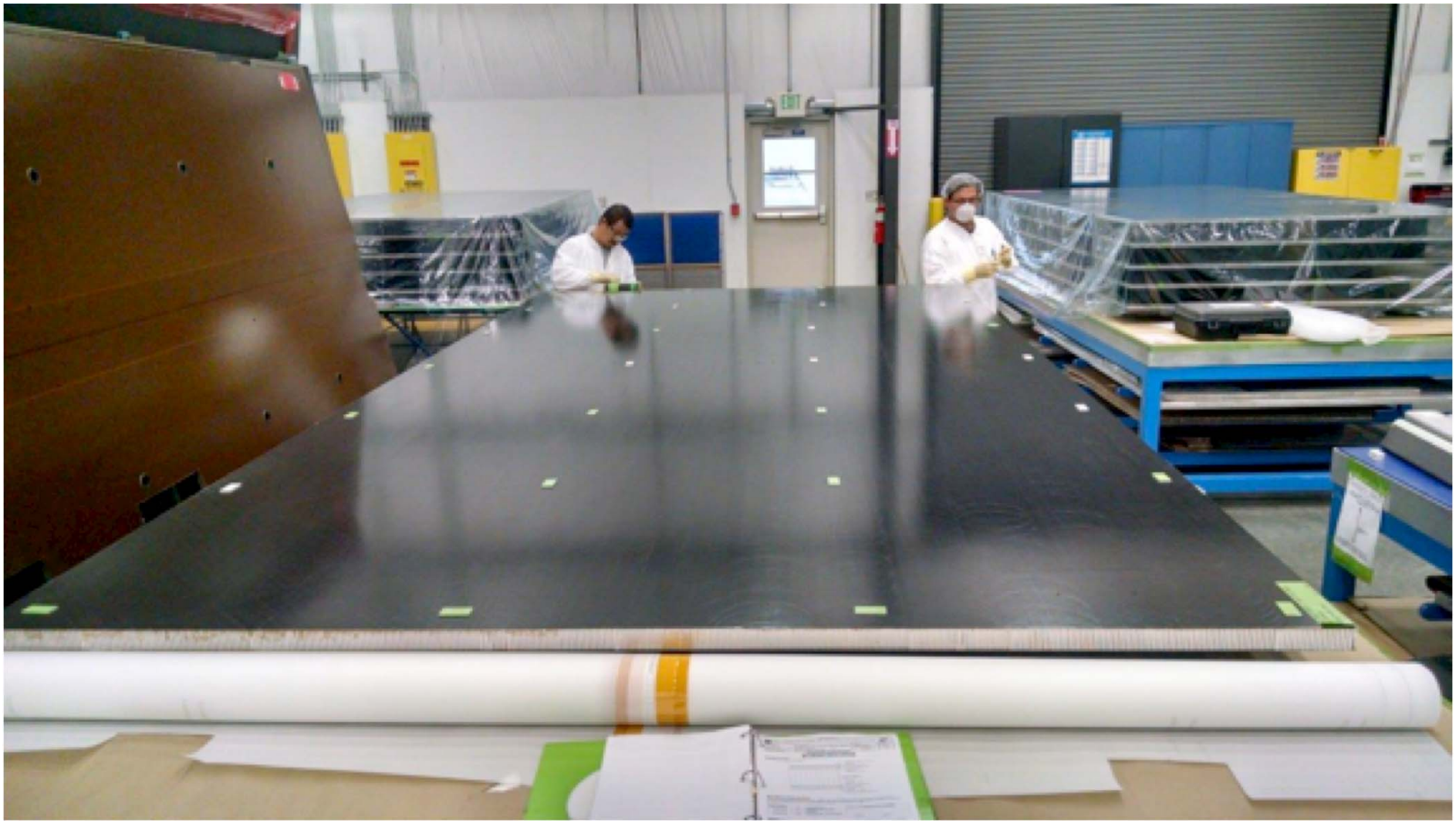
Spacecraft Configuration Update:

4.5 Solar Panels Per Wing



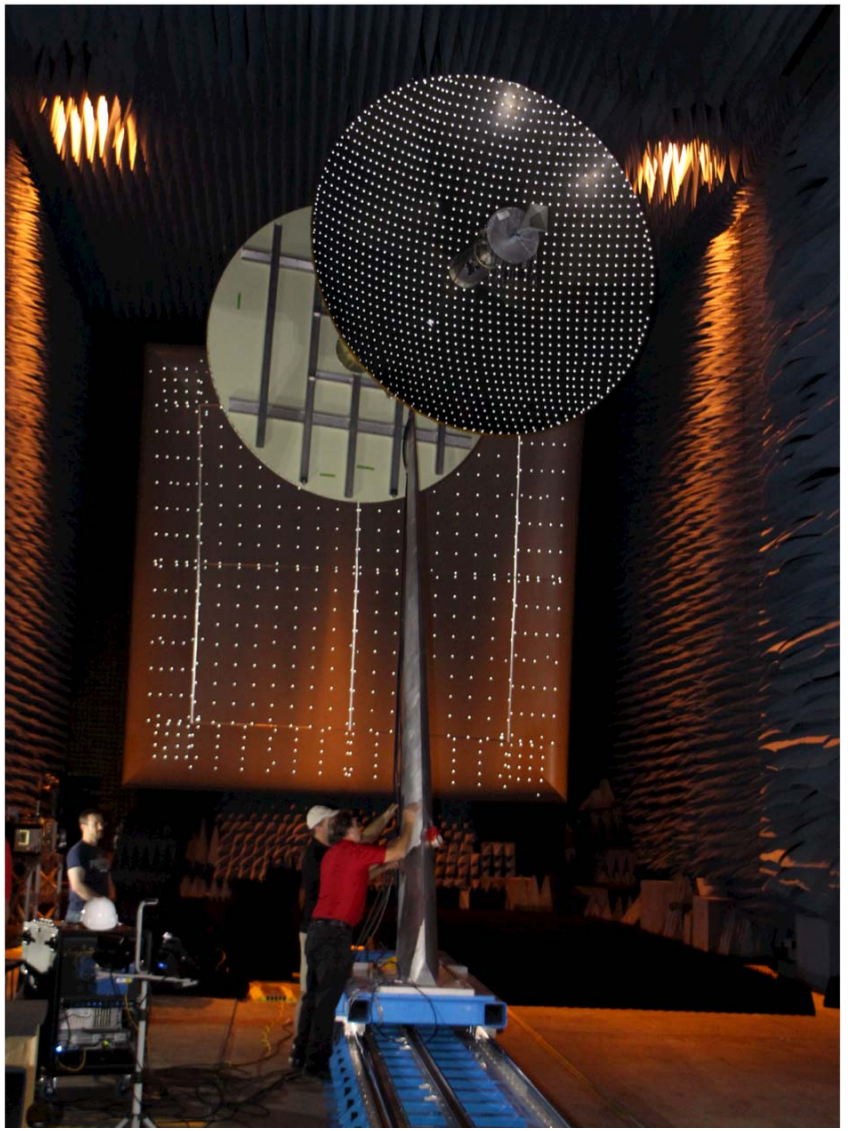
Prototype Hardware

Solar Array Panel Demonstrator



Prototype Hardware

High Gain Antenna



Prototype Hardware

REASON VHF Antenna

'Tis the Season for Preliminary Design Reviews (PDRs)

- **Propulsion Subsystem** 6/27-29/17 (Goddard)
- **Propulsion Module** 7/24-27/17 (APL)
- **Flight System** 10/17-20/17 (JPL)
- **Europa-UVS** 11/15-16/17 (SWRI)
- **PIMS** 12/6-7/17 (APL)
- **REASON** 12/11-12/17 (JPL)
- **EIS** 1/9-11/18 (APL)
- **SUDA** 1/17-18/18 (Univ. Colorado)
- **Solar Array** 1/22-23/18 (APL)
- **Power** 1/24-25/18 (JPL)
- **E-THEMIS** 1/30-31/18 (ASU)
- **ICEMAG** 2/14-15/18 (JPL)
- **Guidance, Navigation & Control** 2/7-8/18 (JPL)
- **Mechanical** 2/12-15/18 (JPL)
- **Thermal** 2/15-16/18 (JPL)
- **Radio Frequency Module / Telecom** 3/14-15/18 (JPL)
- **Radiation Monitors** 4/18 (APL)

- **Avionics** 4/30-5/4/18 (JPL)
- **MISE** 4/25-26/18 (JPL)
- **MASPEX** 5/15-16/18 (SWRI)
- **Fault Management** 5/15/18 (JPL)
- **Mission Design & Navigation** 6/4-5/18 (JPL)
- **Mission Operations System & Ground Data System** 6/6-7/18 (JPL)
- **Project PDR** 8/20-24/18 (JPL)

Spacecraft	Mission System
Payload	Project

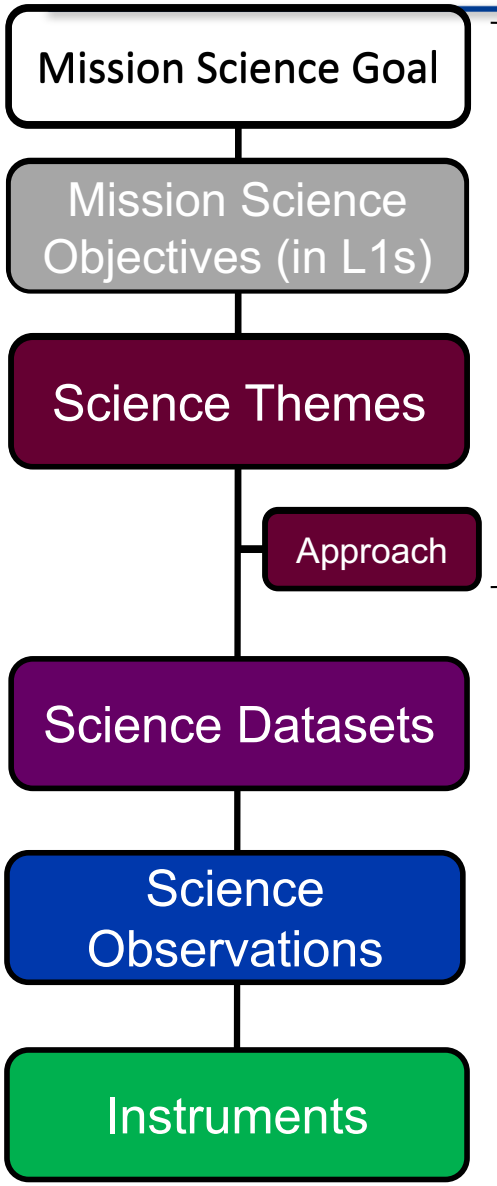
Science Synergy & Redundancy

High Level Roll-Up to Baseline Level-1 Science Requirements

Baseline L1 Req.	Science Themes	Radar		Visible		Infrared	Thermal	UV	Magnetic	Plasma	IMS	NMS	Gravity
		HF	VHF	NAC	WAC								
Subsurface structure of landforms (≥50)	Deep Subsurface Exchange	P	P	S	S								
	Shallow Subsurface Structure	P	P	S	S		E						
Ice thickness; ocean salinity (±50%)	Ice Shell Properties	I	I	S	S		E		P	S			E
	Ocean Properties			E	E	E			P	S	E	E	E
Global comp. map (≥70%)	Global Compositional Surface Mapping			E	E	P		E			E	E	
Landform comp. (≥50%, ≤300 m)	Landform Composition	E	E	E	E	P		I			E	E	
Gas, dust, & plasma composition	Atmospheric Composition	E	E			E		I	I	P	P	P	
	Space Environment Composition					E		P	I	P	P	P	
Global imaging map (≥80%)	Global Surface Mapping			P	P	E	E						
High-res (≤25 m) landforms (≥50)	Landform Geology	E	I	P	P	E	E	E			E	E	
Local surface (~1m, ≥40 sites)	Local-Scale Surface Properties	I	I	P	E		P						
Search for and characterize any current activity	Remote Plume Search and Characterization			P	I	E	E	P					
	In-Situ Plume Search and Characterization	E	E						I	P	P	P	
	Surface Thermal Anomaly Search	E	E	E	E	I	P						
	Surface Activity Evidence	I	I	P	P	I	I	I			E	E	

P Primary I Independent S Supporting E Enhancing

Project Science Traceability and Alignment Framework (P-STAF)



P-STAF Domain

Breakdown of the L1 Requirements into Science Groupings

e.g. Ocean, Ice Shell

Different Ways to Address a Specific Theme

e.g. Induction, Sounding, Gravity

Grouping of Observations/Data from a Specific "Measurement Class" that Support a Specific Theme

e.g. Landform Geology Visible Dataset; Landform Geology Radar Dataset

Unique Combination of Conditions and Techniques that Collect Data to Support Science

e.g. VHF Sounding; Surface Color Monoscopic Images; Impact Mass Spectrometry Endogenic Particles

- STAF framework offers:
  - Traceability
  - Completeness
  - Consistency across instruments
- STAF provides efficiency:
  - Prioritization
  - Tour analysis
  - Mission robustness analysis

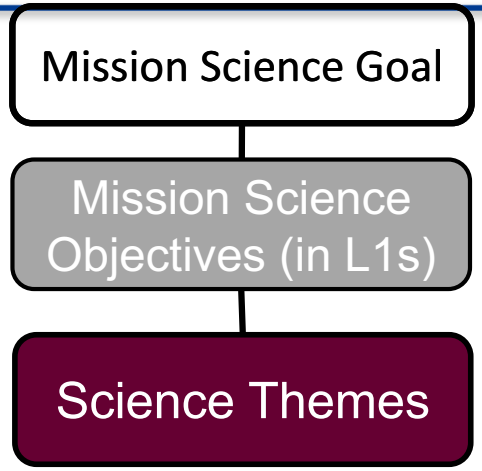
Project Science Traceability and Alignment Framework (P-STAF)

Mission Science Goal

Mission Science Objectives (in L1s)

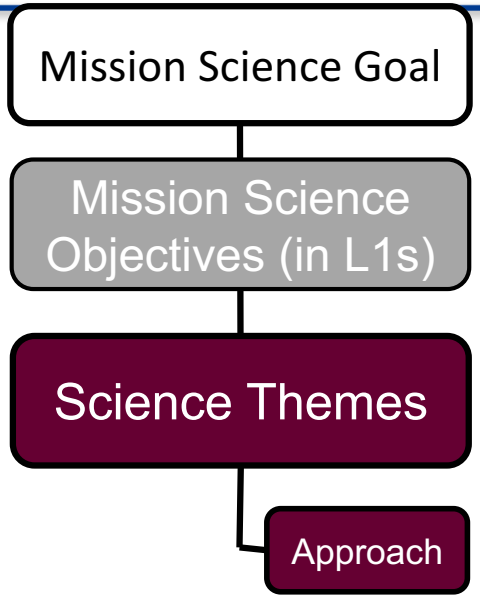
Goal	Category	Baseline L1 Requirements
Explore Europa to Investigate its Habitability	Ice Shell & Ocean	Map the vertical subsurface structure beneath ≥50 globally distributed landforms to ≥3 km depth[, to understand the distribution of subsurface water and processes of surface-ice-ocean exchange].
		Constrain the average thickness of the ice shell, and the average thickness and salinity of the ocean, each to +/-50%.
	Composition	Create a compositional map at ≤10 km spatial scale, covering ≥70% of the surface[, to identify the composition and distribution of surface materials].
		Characterize the composition of ≥50 globally distributed landforms, at ≤300 m spatial scale[, to identify non-ice surface constituents including any carbon-containing compounds].
		Characterize the composition and sources of volatiles, particulates, and plasma, with sensitivity sufficient to identify the signatures of non-ice materials including any carbon-containing compounds, in globally distributed ions of the atmosphere and local space environment.
	Geology	Produce a controlled photomosaic map of ≥80% of the surface at ≤100-m spatial scale[, to map the global distribution and relationships of geologic landforms].
		Characterize the surface at ≤25-m spatial scale, and measure topography at ≤15-m vertical precision, across ≥50 globally distributed landforms[, to identify their morphology and diversity].
		Characterize the surface at ~1-m scale to determine surface properties, for ≥40 sites each ≥2 km x 4 km.
	Recent Activity	Search for and characterize any current activity, notably plumes and thermal anomalies, in regions that are globally distributed.

Project Science Traceability and Alignment Framework (P-STAF)



Goal	Category	L1	Science Themes	Theme Definitions
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Deep vertical distribution of subsurface water, ice shell structure, and surface-ice-ocean exchange processes.
			Shallow Subsurface Structure	Shallow vertical distribution of subsurface water, ice shell structure, and surface-ice exchange processes.
			Ice Shell Properties	Thickness and thermophysical properties of the ice shell.
			Ocean Properties	Existence, thickness, and salinity of the ocean.
	Composition		Global Compositional Surface Mapping	Global surface composition and chemistry, including distribution and large-scale variability of materials.
			Landform Composition	Surface constituents, focusing on non-water-ice and any carbon-containing compounds, on a regional and landform scale.
			Atmospheric Composition	Composition and sources of non-ice volatiles, particulates, and plasma in the atmosphere, ionosphere, and possible plumes, within Europa's Hill Sphere (<8.5 R_E).
			Space Environment Composition	Composition and sources of non-ice volatiles, particulates, and plasma in the space environment, outside of Europa's Hill Sphere (>8.5 R_E).
	Geology		Global Surface Mapping	Global distribution and relationships of geologic landforms.
			Landform Geology	Morphology, topography, geology-composition correlations, and diversity of landforms.
			Local-Scale Surface Properties	Local-scale morphological, thermophysical, and mechanical surface properties.
	Recent Activity		Remote Plume Search and Characterization	Remote detection and characterization of active plumes and their extent above the surface of Europa.
			In Situ Plume Search and Characterization	*In situ* detection and characterization of recent or active plumes.
			Surface Thermal Anomaly Search	Thermal signatures of current or recent geological activity.
			Surface Activity Evidence	Surface properties and/or changes indicative of current or recent activity.

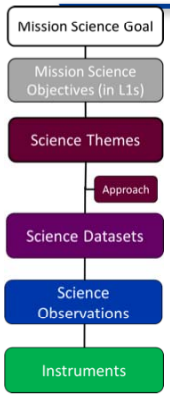
Project Science Traceability and Alignment Framework (P-STAF)



Developed by the Project Science team to better understand how instrument groupings approach a given science theme

Goal	Category	L1	Science Themes	Baseline Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding, Shape and Gravity
			Ocean Properties	Induction, Shape and Gravity
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	Morphology, Roughness and Permittivity
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes

Full P-STAF Matrix (In Progress)



Science Observations by Measurement Class

L1, Science Theme, Approach

P
Primary

I
Independent

S
Supporting

E
Enhancing

?
In Progress

- A primary instrument (P) is not required in every row.
- If an approach has no primary instrument, then that approach is considered less robust.

P-STAF Analysis (Still To Come)

Once the inputs are reconciled and vetted, the P-STAF can be used to determine:

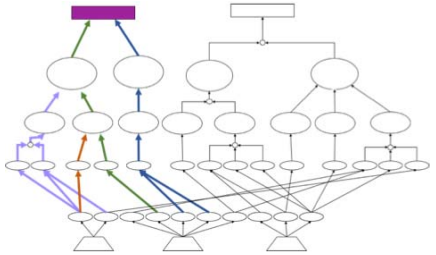
"Simple" queries to the network include:

- In how many independent ways can each Level 1 be met?
- Which Level 1s have single points of failure?
- If an instrument or observation fails, which Level 1s are not achievable?
- How many paths does an instrument affect?

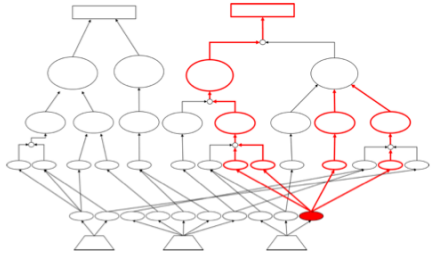
"Complex" queries to the network include:

- How resilient is each Level 1 to failures?
- What is the impact of a given observation or instrument?
- What is the minimum set (of instruments or observations) necessary to meet a Level 1 or a group of Level 1s?
- Which Level 1s require the most resources to meet?

Robustness
Number of Viable Paths



Criticality
Single Point Failures



Scope
Link Density of Nodes